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Comment on "Measuring the Orbital Angular Momentum of a Single Photon"

Haiqing Wei[1,2,*] and Xin Xue[1]
[1] *Gazillion Bits Incorporated, 110 Rose Orchard Way, San Jose, California 95134*
[2] *Department of Electrical & Computer Engineering, McGill University, Montreal, Canada H3A-2A7*

Optical modes with different orbital angular momentums (OAMs) per photon may be sorted by Mach-Zehnder interferometers incorporated with beam rotators, without resorting to OAM mode converters.

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Presented in a recent letter [1] is an ingenious method of sorting spatial modes of photons with different orbital angular momentum (OAM), which closely resembles, and in a sense complements a scheme of analyzing optical beams with rectangular symmetry [2]. The method in [1] employs special Mach-Zehnder (MZ) interferometers as binary branching devices, each of which divides a set of input modes with $l \equiv k \pmod{2^n}$ into two groups with $l \equiv k \pmod{2^{n+1}}$ and $l \equiv 2^n + k \pmod{2^{n+1}}$ respectively, where the integer l denotes the single-photon OAM in units of $\hbar$, k and n are fixed, non-negative integers specific to the individual interferometer. In the Letter, the same condition is assumed implicitly for all the MZ interferometers, that one arm maintains zero phase (or integral multiples of 2π) for all the modes, while the other arm rotates the beam by an angle α so to induce an OAM-dependent phase shift $l\alpha$. The assumption proves rather restrictive and responsible for the necessity of OAM mode converters, which result in optical loss and increase significantly the complexity of the optical setup. The loss of light could impose a serious limitation to quantum optical experiments involving single photons.

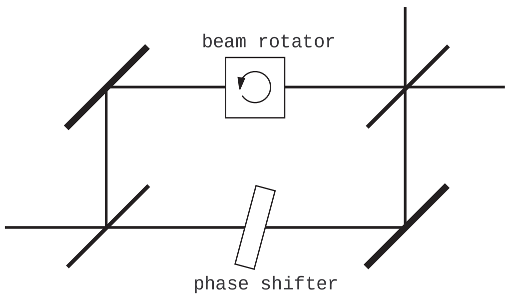

FIG. 1: A modified Mach-Zehnder interferometer.

The use of OAM mode converters may be avoided by relaxing the aforementioned restriction on the MZ interferometers, namely, by incorporating an adjustable phase shifter in a modified MZ interferometer as depicted in Fig.1. In practice, there is always a mechanism of phase adjustment in setting up an optical interferometer. An example implementation is a thin glass film making an adjustable angle to the beam axis. When OAM modes with $l \equiv k \pmod{2^n}$ are input into the modified MZ interferometer, the beam is rotated by $\alpha = \pi/2^n$ in the upper arm such that a mode with OAM l acquires a phase $l\alpha = l\pi/2^n$, while the phase shifter in the lower arm is tuned to induce a fixed phase shift $k\alpha = k\pi/2^n$ to all the OAM modes. It is easily seen that the modified MZ interferometer segregates the OAM modes into two groups with $l \equiv k \pmod{2^{n+1}}$ and $l \equiv 2^n + k \pmod{2^{n+1}}$ respectively. Such modified MZ interferometers may be used as binary branching devices to construct an OAM mode sorter, without resorting to OAM mode converters.

The OAM mode sorter is in striking similarity to the Hermite-Gaussian (HG) mode analyzer using MZ interferometers incorporated with fractional Fourier transformers (FRFTs) [2]. FRFT-incorporated MZ interferometers can even be used after an OAM mode sorter to lift the mode degeneracy due to the radial degree of freedom, so that orthogonal Laguerre-Gaussian (LG) modes can be sorted completely. Moreover, a complete HG mode sorter may be utilized just as a complete LG mode analyzer with the help of HG $\rightleftharpoons$ LG mode converters [3]. Finally, it may be noted that the increased information capacity using higher order OAM [1, 4] or HG modes is just the result of an enlarged spatial channel [5]. To achieve the higher capacity, the spatial channel needs to support optical beams with larger sizes than the fundamental mode.

* dhwei@gazillionbits.com

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